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Cost estimation of stereotactic radiosurgery: application to Alberta

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Institute of Health Economics, and
University of Alberta, Department of Public Health Sciences

May 2003

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This Health Technology Assessment Information Paper has been prepared on the basis of available information of which the Foundation is aware from public literature and expert opinion, and attempts to be current to the date of publication. Comments received following circulation of the draft have been considered in preparation of the final report.

Additional information and comments relative to the paper are welcome, and should be sent to

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- Dr. Michael West, Health Sciences Centre, Winnipeg, Manitoba

ABBREVIATIONS

AVM = Arteriovenous malformations
CK = CyberKnife
CMA = Cost minimization analysis
CNS = Central nervous system
CT = Computerized tomography
DM = Deutchmark
DRG = Diagnostic related grouping
EQ-5D = Euro Quality of Life 5 dimensions
FTE = Full time equivalent
GK = Gamma Knife
LINAC = Linear accelerator
LYS = Life years saved
MRI = Magnetic resonance imaging
QALY = Quality adjusted life year
SD = Standard deviation
SF-36 = Short form - 36
SRS = Stereotactic radiosurgery (single procedure)
SRT = Stereotactic radiation therapy (multiple procedures)
US = United States
WBR = Whole brain radiation therapy

CONTENTS

Acknowledgements i

Abbreviations ii

Objective and Context of the Study 1

Description of the Technology 2

Accuracy and Effectiveness of SRS 4

Methodology 6

  Patient group 6

Cost Model 9

  Fixed Costs 9

  Variable costs 11

Results 14

Alternatives for Alberta and Western Canada 18

Discussion 19

Conclusions 23

Appendix A: Personal Communication Details 25

Appendix B: Koningsmaier et al.cost model results 26

Appendix C: Workload Projections/annum in Alberta 28

Appendix D: Fixed Cost Comparison for CK, GK and LINAC 29

References 31

Tables:

Table 1: Annual cost estimates for health care staff for a dedicated SRS unit 11

Table 2: Novalis® average costs per patient 14

Table 3: Gamma knife average costs per patient 15

Table 4: CyberKnife average costs per patient 15

Table 5: Distribution (%) of costs for each SRS modality 15

Table 6: Equipment purchase and annual operating costs (Konigsmaier et al.) 26

Table 7: Total cost of treatment per patient based on equipment used (Konigsmaier et al.) 27

Table 8: Estimated number of Alberta patients who would qualify for SRS 28

Table 9: Fixed cost comparisons 29

OBJECTIVE AND CONTEXT OF THE STUDY

The purpose of this study is to provide economic information to decision makers in Alberta Health and Wellness about the treatment alternatives for neurosurgical patients requiring stereotactic radiosurgery (SRS). From the Ministry's view, the relevant question is: what is the most cost-effective way to offer SRS services to those neurosurgical patients in Alberta who are appropriate for this procedure. The aim of this report is to provide cost estimates for the three main SRS technologies: Gamma Knife (GK), CyberKnife (CK) and LINAC (Novalis®). Cost factors are estimated and valued based on provincial data, as available.

The Tom Baker Cancer Centre in Calgary has one modified linear accelerator (LINAC) unit that is used to treat some malignant neurosurgical patients. The existing LINAC unit at the Tom Baker Cancer Centre does not have any extra capacity to be modified for the treatment of selected patients with non-malignant tumors/conditions (acoustic neuroma, arteriovenous malformations, pituitary tumors, etc.). A modified LINAC unit consists of a basic LINAC that is equipped with specific SRS technologies. Because the modified unit requires additional quality assurance procedures and does not have sufficient capacity, the specialists in Calgary are interested in establishing a dedicated SRS unit operated with a highly qualified team.

Another treatment option for patients requiring SRS to treat non-malignant tumours would be to send these patients to SRS units available out of province. Traditionally some have been sent to the United States or Europe for these services. Patients have also been sent to LINAC units in eastern Canada.

The Winnipeg Health Sciences Centre in Manitoba has recently purchased a GK unit, and will be offering services to patients from other Western Canada provinces some time at the end of 2003.

This report concentrates on the utilization of SRS in the treatment of patients with tumours or conditions in the head/neck area. Novalis® and CK technologies can also be used to treat other parts of the body.

The report utilizes cost minimization analysis (CMA) for the comparison of the costs of the alternatives [1]. The basic assumption in the CMA is that the effectiveness of the assessed technologies is the same and there is evidence from other studies [2, 3] suggesting that this assumption is supported.

This report does not compare the effectiveness of the SRS technologies and microsurgery. Conventional microsurgery and radiosurgery are complementary or adjunctant for patients with glioblastoma and arterio-venous malformations (personal communication Dr. Barton). Comments about experience and costs with microsurgery are provided when information was available. Comparisons are not included in the model but provided as ancillary information.

DESCRIPTION OF THE TECHNOLOGY

SRS has been in clinical use for about three decades [4]. SRS is non-invasive and utilizes a radiation technique to remove lesions within the brain (or other organs). It is mainly used for small brain lesions (mostly less than 3 cm). This restriction limits the use of SRS to a portion of all neurosurgical patients. Imaging, planning, and the procedure itself are done in a 3-dimensional environment to ensure maximal accuracy. The tumor or other tissue is specifically targeted for radiation while sparing surrounding healthy tissue. Patients are treated during a single session in an outpatient clinic.

Fractionated Stereotactic Radiation Treatment (SRT) involves several sessions over a period of days or weeks. One advantage of fractionation is that it may protect more of the healthy tissue surrounding the tumour. It can be used for larger lesions and for lesions located near critical structures.

Basically there are three different kinds of technology available for SRS treatments:

- The Leksell Gamma Knife® is one of the two most commonly used SRS technologies. It utilizes a total of 201 cobalt-60 sources arranged in a hemispherical pattern and embedded within the shielded, dome-shaped radiation unit. The basic system includes the radiation unit with the patient couch and collimator helmet, the control panel and auxiliary systems. The SRS team using MRI and CT images and the specific treatment planning software determine the exact coordinates within the patient's head for placing the invasive frame by the neurosurgeon. The determination of the exact coordinates within the patient's head is similar for all SRS technologies. All patients treated in GK units require the placement of an invasive frame pre radiation, making fractionation less desirable.
- The modified linear accelerator which is manufactured by several companies is another widely used SRS technology. Novalis® is an example of a commercially available system of this type of equipment. The conventional LINAC produces photons from a single point by rotated arcs or sets of arcs. The radiation beam is directed at the target lesion for the entire treatment time but passes through other parts of the brain momentarily [5]. Prior to treatment, the head of the patient is immobilized by a frame. By increasing the dose rate, reducing the machine weight, and targeting the beam, modified LINACs for SRS treatment are more accurate than conventional LINACs. Novalis® also has an electronic x-ray imager that assures accurate beam placement and sites outside the brain can also be treated.
- The new emerging SRS technology CyberKnife is basically a small LINAC that is moved around the target lesion by robotic technology. During the CK procedure the patient's head is kept immobile. The CK unit includes a video location system that can be used to locate the target point based on the patient's facial features. This is

useful for fractionated SRT where patients get doses over several treatment days. Low dose rate treatments are used for fractionated SRT. Ninety percent (90%) of patients would be suitable for high dose single fraction treatments (personal communication, Dr. Barton).

In addition to the GK, Novalis® and CK there are some new emerging SRS technologies. Since they are significantly more expensive and are not commercially available [2], they are not considered in the current report.

ACCURACY AND EFFECTIVENESS OF SRS

The accuracy of these three SRS technologies is difficult to compare. It is argued that the GK has the highest accuracy of the SRS technologies as there is no movement of the radiation source and LINAC moves during treatment [6]. The development of the new LINAC technologies has improved the accuracy of the dedicated LINAC units [2]. According to Schwartz [5] the spatial accuracy of the radiation device is only one aspect of accuracy; imaging, target choice, dose calculation, and setup may be even more important factors. In this report, it is assumed that the accuracy of the GK, Novalis® and CK technologies do not differ significantly from each other. In addition, there are no good studies comparing the clinical accuracy and its significance among these three SRS technologies.

The effectiveness of the different SRS technologies and the possible difference between SRS and conventional microsurgery has been assessed in several recent reviews [2,3,7]. Both Canadian reviews [2,3]concluded that there is no evidence that the effectiveness of the GK and LINAC technologies would differ significantly from each other and from conventional microsurgery. However, these conclusions are not based on results obtained in randomized controlled trials. In the Alberta Heritage Foundation for Medical Research review [3], the following results were summarized:

- The quality of the available information on SRS effectiveness in comparison with other types of treatment is limited.
- There is still no evidence that any one form of SRS is superior over another.
- There is increasing use of fractionated SRT as an alternative or supplement to SRS. There is some indication, from a small series of data, that fractionated SRT may have advantages over SRS in terms of incidence of complications in some situations.
- SRS, using robotic technology (the CK), is now available; this technology enables treatment in any part of the body. Preliminary clinical results have been published.
- There is a need to go beyond cost analysis to the economic evaluation of SRS technologies, taking appropriate account of local circumstances.
- It is essential to have quality assurance and to ensure that the SRS unit is located in a specialized centre.
- SRS can be used for acoustic neuroma patients where surgery may have an unacceptable risk or be refused; in arteriovenous malformations (AVM) as a complementary approach to surgery when the lesion cannot be safely operated; in selected brain metastases; and in brain tumour patients.
- More evidence is needed relating to applications to trigeminal neuralgia, Parkinson's disease and epilepsy (functional disorders).

There are no randomized controlled trials on the cost-effectiveness of SRS technologies. Rutigliano et al. [8] compared microsurgery with whole brain radiotherapy (WBR) and SRS (GK) with WBR to WBR alone for solitary metastatic brain tumors using values from the medical literature published between 1974 and 1994. Their study showed that the cost-effectiveness of microsurgery with WBR was US $32,149 per life year saved (LYS) and for SRS with WBR was US $24,811; the incremental cost effectiveness per LYS year when each alternative is compared to WBR alone was US $52,384, and US $40,648, respectively. Mehta et al. [9], using a comparable study methodology to that of Rutigliano et al., also found that for single-brain metastases radiosurgery with WBR was more cost-effective and had a better cost per quality adjusted life-year (cost/QALY) ratio than microsurgery with WBR. However, the QALY results were based on physician valuations using the Karnofsky Performance Score; such a measurement tool is not widely used in economic analysis.

METHODOLOGY

The SRS cost estimate is based on a hypothetical cost model, meaning that most of the quantities of cost factors and their values are not directly observed and measured in a real life situation. The reason for that is that there is no dedicated neurosurgical SRS unit in Western Canada. However, the Tom Baker Cancer Centre in Calgary has used one LINAC unit to treat malignant tumours in selected patients.

It is assumed that the SRS unit is a dedicated unit for the treatment of selected patients, staffed and operated by a specific team of experts. This will ensure a high quality of services and, with a dedicated unit, the quality control costs will be reduced [2, 3]. It is also assumed that the SRS unit will be equipped with new equipment.

In the construction of the cost model the following persons have provided information: Dr. Alexander Chan and Dr. Peter Craighead, Tom Baker Cancer Centre, Dr. Kenneth Petruk, Neurosurgical Department, University of Alberta, and Dr. Garnette Sutherland, Department of Clinical Neurosciences, University of Calgary (see Appendix A). All costs in the model are shown in Canadian dollars using 2002 values (where possible). Also, extensive use has been made of the cost model by Koningsmaier et al. (see Appendix B) [10]

Although SRS will be used for several different indications, it seems realistic to assume that the resource utilization of these treatments is similar. The exception is for patients who receive fractionated SRT and could require up to 10 sessions. To enable proper comparison of the costs of the GK and the other two technologies, the fractionated SRT cases are not included in the calculation. The costs are presented as an average cost per patient.

Costs for SRS technologies are divided into direct medical costs and patient – borne cost categories. The direct medical costs include costs for the equipment and construction of the facility, monthly salary of the staff, supplies, and equipment maintenance. All the medical costs are assumed to be fixed, since the SRS unit is assumed to be a dedicated unit. The SRS related variable costs are assumed to be insignificant, since most patients do not require hospitalization after SRS. The diagnostic tests (e.g. MRI and CT images), post-SRS treatments (whole brain radiation, medication), and follow-up procedures are assumed to be similar for all SRS technologies, and the conventional microsurgery alternative. The costs for any of these services are not included in the model. Patient-borne costs included are hotel costs during the visit at the SRS centre, lost working time (indirect cost) due to the procedure, and the costs of the caregiver who is required to accompany the patient during the SRS visit.

Patient group

It is assumed that these technologies are mainly used for patients requiring neurosurgery. The assumed patient groups are patients with tumours in the head/neck area such as acoustic neuromas, brain metastasis, glioma, AVM, and trigeminal neuralgia [1]. SRS is suitable and potentially beneficial only to a proportion of these patient groups [2].

The estimated numbers of the potential patients for SRS treatment came from preliminary projections by two groups of Albertan physicians (see Appendix A), from Calgary (personal communication, Dr. Chan and Dr. Craighead) and from Edmonton (personal communication, Dr Petruk) (see Appendix C for workload projections).

The Calgary physicians estimated that 185 new cases per year from Alberta and 63 new cases per year from British Columbia (based on 25% estimate of BC population) would benefit from dedicated SRS services. These estimates do not include functional neurosurgery, temporal lobe epilepsy, and cognitive neurosurgery cases. If 30 patients of the estimated 248 patients would receive fractionated SRT, that is 10 fractions per patient, the total number of procedures per year would increase to 518 (218 single treatments and 300 fractionated procedures). Fractionated SRT is used only with CK and Novalis® techniques, since it is possible to continue with patient's treatment plans over a period of several days without requiring extensive quality assurance procedures [3].

The Edmonton physicians estimated that 130 to 150 patients per year, which included 10 functional neurosurgery patients, 15 patients with temporal lobe epilepsy and five cognitive neurosurgery patients, would qualify for SRS according to clinical presentation. Since the University of Alberta provides combined neurosurgery/otolaryngeology services to patients from Saskatchewan, British Columbia and the Northwest Territories, the estimated numbers of patients with acoustic neuroma (benign tumors) and those requiring cognitive neurosurgery who would potentially require SRS are included in these estimates (personal communication, Dr. Petruk).

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[1] The SRS has also been used for an increasing number of other functional disorders, like Parkinson disease, epilepsy and some psychiatric patients. However, the effectiveness of the SRS in functional neurosurgery is not well established (AETMIS 2002, Hailey 2002). In addition to the target lesions in the head, LINAC modality is being investigated for spinal cord, limited lung and certain liver tumors.

[2] The AETMIS (2002) report estimated that the number of SRS patients in Quebec would be about 300 cases per year, and 40 patients per million. However, some experts gave higher estimates for the patient load (180 per million) in Quebec (AETMIS 2002). The estimate of 40 patients (metastases, schwannomas and vascular malformations) per one million population per year would mean that the number of patients in Alberta would be about 120 patients per year. In addition there would be some out of province patients.

[3] The newest GK techniques allow also some fractionation to be done during one procedure session; however, patients are treated very seldom during several treatment days due to the need to attach the frame to the skull of the patients on every treatment day.

As it is assumed that an SRS unit would be dedicated to SRS alone with its own full time staff complement, the cost model does not make any provision for patient loads less than 100 per year, since at lower volumes the service of this team of experts would not be appropriately utilized. The upper patient load for SRS treatment by the team of experts is difficult to determine.

COST MODEL

The basic construction of this model is adopted from the model developed by Koningsmaier et al. [10]. Most of the resource utilization and cost valuation information have been modified to correspond to the Alberta health care system, including recent cost estimates for SRS technologies and health staff salary estimates (personal communication Dr. Peter Craighead and Dr. Alexander Chan). Some cost estimates were adopted from the Koningsmaier et al. model. These cost estimates from Koningsmaier et al. have also been recently used in a Quebec report [2] (see Appendix B).

Fixed Costs

The following costs are assumed to be fixed as they do not tend to vary with the number of patients treated per time period (see Appendix D). However, a substantial increase in the volume of patients may increase some of these costs; for example, due to the need for overtime.

Construction costs

The Tom Baker Cancer Centre has an area that can be altered for SRS purposes. It is estimated that such a changeover would cost $550,000 for CK, $150,000 for renovation and millwork for Novalis® and $1,000,000 for GK. It should be noted that if the SRS unit would need a new location, the construction costs for Novalis® and CK would probably be a bit more expensive than for GK [2]. It is also assumed that the new SRS unit would be operational for 25 years.

Equipment investment costs

It is difficult to obtain exact values for investment costs for SRS equipment as each centre negotiates different terms with the various manufacturers. The differences in currency exchange rates may also influence investment costs. The investment cost for CK is estimated to be $4.5 million, for Novalis® $4.32 million and for GK $5.5 million. The investment cost estimates for Novalis® and CK are a bit uncertain since the equipment has been available on the market for only a short time.

The duration of life for both CK and Novalis® is estimated to be 10 years and for GK 15 years. Some GK cost studies have used a 20-year lifetime [10, 11]. In addition, GK requires a replacement of the cobalt-60 radiation unit every 5 to 10 years.

Cobalt sources have a half-life of about 5 years, meaning that the radiation procedure times are twice and four times longer after 5 and 10 years of utilization, respectively, compared to the first year treatment times. It is assumed that a replacement of the radiation unit is made twice (every 5 years) and the estimated replacement cost is $956,000 (current value). Added to this is the cost for the removal and disposing of the old sources (about $200,000).

Investment costs are distributed over the lifespan of the equipment and facility construction. The capital cost of the investments is calculated using a 5% annual interest rate in an annuity calculation. The replacement cost of a cobalt-60 radiation unit and the dumping of the discarded unit are first evaluated at the end of the period using the 5% interest rate, and then the total costs of these annual terms are divided into the 15 year lifetime of the GK. This approach allows for the estimation of fixed capital costs for each of the alternatives and also includes an opportunity cost for the investment.

Maintenance costs

All three types of SRS require maintenance. Since GK does not have moving components, the maintenance is mainly covered in a service contract. The estimated value of the service contract per year is $138,700 (about US$90.000; one US$=1.5416 Cdn$ June 2002). The same service contract estimate has also been used in CK and Novalis® technologies (Dr. Alexander Chan and Dr. Peter Craighead, personal communication based on costs paid by US SRS centres). In addition to the service contract, CK and Novalis® require technical maintenance. For CK the maintenance cost is $176,974 starting in the second year (Dr. Alexander Chan) and for Novalis® it is estimated to be $73,400 per year (Koningsmaier et al.[10]: DM 99,000, Cdn $1=1.348DM June 2002).

Supply costs

The basic supplies used by each technology are about the same. The cost for dosimetry, nursing support, hardware cost, and intra-venous contrast is estimated to be $109,570 (personal communication, Dr. Chan). The cost for cleaning is $13,500 for each alternative and the cost of electricity and water is $2,500 for both GK and CK, and $10,300 for Novalis® (Koningsmaier et al. [10]). Although the costs of supplies are partly variable in nature, in this study they are assumed to be fixed, because small variation in these costs according to the number of procedures would not have significant impact on the cost analysis. In addition, GK requires a radiation test that is conducted four times per year, at a total estimated cost of $17,800 (personal communication, Dr. Chan). The Novalis® and CK are assumed to require only one radiation test per year (Koningsmaier et al. [10]) at a cost of $4,450.

Staff costs

To staff the dedicated unit on a full time basis means that staff cost estimates are fixed during a given time period. The GK unit can be run with less staff than the CK and Novalis® units, partly because GK cannot be used for purposes other than neurosurgical services. Also, the possible alternative of fractionated SRT for some of the patients (resulting in multiple procedures) may increase the number of staff needed for either CK or Novalis® services when compared to the staff component requirements for GK. The cost estimates in Table 1 do not include any staff education costs, cost of hiring personnel for sickness leave and other reasons, or possible overtime. The cost model of

Koningsmaier et al. [10] used the same assumptions up to a patient load of 200 patients per year, and beyond that point staff costs were assumed to increase by 20%.

The influence of staffing requirements on the costs has been varied in the sensitivity analysis. It is likely that for low patient volumes (100 – 150 patients) the neurosurgeons do not need to use all of their working time for SRS patients. As there currently is no fee-for-service reimbursement in Alberta, 50% of the neurosurgeon's salary was used to estimate the staff costs to operate a dedicated SRS unit with a workload of up to 200 patients per year. The total cost estimate will be impacted if the neurosurgeon and radiation oncologist would be paid on a fee-for-service or case by case basis rather than by salary (personal communication, Dr. Lance). Novalis® LINAC based units often utilize three to four radiology technicians (personal communication, Dr. Barton). Reflecting the possible need for additional radiology technicians for higher patient volumes, a sensitivity analysis was conducted using three technicians for CK and Novalis® when the patient load was over 200 per year.

Table 1: Annual cost estimates for health care staff for a dedicated SRS unit

Staff member	CyberKnife	Novalis®	Gamma Knife	Salary/year
Receptionist	1	1	1	$33,000
Clerical support (Clerk III)	1	1	0.5	$36,000
Nurse clinician	1	1	1	$76,358
Radiology technicians	2*	2*	1	$69,000
Radiation Oncologist	0.5	0.5	0.5	$150,000
Neurosurgeon	1 (0.5)**	1 (0.5)**	1 (0.5)**	$300,000
Medical physicist	1	0.5	0.5	$85,000

Source: Calgary Health Region (personal communication, Dr. Alexander Chan and Dr. Peter Craighead).

*It is likely that LINAC based technologies would require three radiology technicians (Dr. Barton, personal communication).

**0.5 of a neurosurgeon's time is used in the sensitivity analysis on low patient volumes (100-200 patients).]

Variable costs

Since the SRS procedures will mainly be done on an outpatient basis and the staff is on salary, there are no significant variable cost factors in these calculations. The cost of complications (e.g. hemorrhage during AVM) related to SRS could be added to these cost estimates, however they are difficult to estimate for a hypothetical patient population. In addition, it is likely that a variation in these costs may not be significant among the technologies.

Patient costs/indirect costs

Patient costs include three components: lost working time due to treatment, travel costs, and hotel costs. The SRS procedure is planned to take place during a one-day outpatient visit. Since patients have a small risk for complications after the procedure, they are usually required to stay in a hotel overnight after the procedure. For safety reasons, patients who are treated with SRS need a companion caregiver. It is estimated that indirect costs due to lost working time consist of a one-day visit to the hospital and one additional day for all GK patients and most CK and Novalis® patients. As mentioned previously, 30 patients requiring the Novalis® and CK technologies will need ten visits to the facility (fractionated stereotactic treatments). It is unlikely that GK will be used for fractionated SRT. If the patient and the caregiver are from out of town they would require a 12 night stay in a hotel.

For the calculation of indirect costs it is assumed that patients are absent from work for two days after the procedure (personal communication, Dr. West), although one working week of sick leave after the procedure is used in one study [12]. A patient's total lost working time for a one-day procedure is three days, and for a 10 day fractionated SRT is 12 days. The caregivers lose 2 and 11 working days, respectively. It is assumed that the average income of a patient or caregiver is about $30,500 per year (Statistics Canada estimates for year 2000) and the daily income is $121. It should be noted that a significant proportion of patients who require SRS and their caregivers do not work, and thus they do not incur lost production costs due to sickness. Hotel costs for out of region patients and caregivers are assumed to be $150 per day (double room) and they are assumed to arrive a day prior to the procedure.

If the Alberta patient travels to another province or abroad for SRS services, Alberta Health and Wellness will reimburse the travel costs. All travel (to and from the airport, to and from the hospital) costs are reimbursed for both the patient and the caregiver (estimated to be $400). An airline ticket for travel from Alberta to Winnipeg, for example, costs approximately $389. Hotel costs for two nights are about $300 ($150 per night). Because the patient has to travel to Winnipeg one day before the procedure, the total number of days absent from work will be four days for the patient and three days for the caregiver ($121 per day).

Cost of microsurgery

The cost estimate for microsurgery is complicated by the fact that SRS is used to treat several different types of diseases and no single cost estimate for conventional surgery can be calculated. There is an emerging consensus amongst neurosurgeons and radiation oncologists that there is a population with intracranial lesions, such as acoustic neuromas, that should be treated with SRS rather than microsurgery. Treatment with SRS seems to reduce cranial nerve damages and preserve mobidity and hearing in some patients (personal communication, Dr. West).

The most comprehensive Canadian cost estimate for microsurgery was provided by Mendez et al. [13] for patients with glioblastoma multiforme treated between 1996 and 1998 in Nova Scotia. Mendez et al. [13] estimated that the mean cost of caring for patients with glioblastoma multiforme from diagnosis to death was $20,559 (SD $8,224) for those who underwent craniotomies and $14,782 (SD $7,195) for those who underwent biopsies. The higher costs for patients who had craniotomies were related to the length of the hospital stay. The number of cases in each of these treatment groups was 25 and 36 patients respectively and the average number of days of survival from diagnosis to death was 206 days (SD 189 days). Mendez et al. [13] calculated that the initial treatment period, including hospitalization, surgery, and physician costs covered 64% of all medical costs. The initial treatment cost for patients undergoing craniotomy was $13,158. This value will be used as a crude proxy for the cost estimate of microsurgery for the treatment of patients with tumours in the head/neck area. The cost comparisons used in this model only provide a very rough estimate of the relative costs for the different technologies.

In the Quebec report, the DRG-based costs for craniotomy without complications varied from $5,366 in Manitoba [14], $8,256 in Quebec [15] to $9,466 in Alberta [16, 17]. The main reason for different cost estimates in the provinces is due to the variation in the length of hospitalization, 6.3 days in Manitoba and 9 days in Quebec [2]. The Alberta cost estimate also includes the physician cost using 1996 prices, whereas the Manitoba and Quebec estimates do not include physician costs. It should be noted that if microsurgery is used for multiple metastatic brain tumors, it would reguire multiple surgical approaches and hospitalizations, while with SRS the patient's tumours may be treated during the same treatment sessions (personal communication, Dr. West).

Although it may be reasonable to assume that all SRS procedures utilize about the same amount of resources, a microsurgical operation for different diseases requires different amounts of resources. To simplify the cost comparison of conventional microsurgery, the estimated medical costs for each possible patient group was not calculated. It seems that Alberta and Nova Scotia cost estimates for microsurgery are most comparable to the SRS costs. Since conventional microsurgery does not require extensive investment in direct equipment, patient volumes do not significantly influence the cost.

For patients undergoing conventional microsurgery, sickness leave is estimated to be six weeks, although in some countries it can be up to three months [12]. The six weeks absence from work is based on the average sickness leave for patients with acoustic neuroma (personal communication, Dr. West). The required sickness leave for patients is difficult to estimate for all disease groups since the operations are not equivalent and the healing processes vary. Travel costs within Alberta are basically the same as would be for the SRS option.

RESULTS

The basic cost models for all three SRS modalities are shown in Tables 2, 3 and 4, respectively. Table 5 presents the distribution of costs for each type of SRS modality. When comparing total health costs Novalis® technology appears less costly than GK and GK appears less costly than CK. At the lowest assumed volume of procedures, 100 patients per year, the total health care costs per patient was $16,210 for Novalis®, $16,856 for GK, and $18,187 for CK. At a workload of 200 patients per year, the costs per patient were $8,105 for Novalis®, $8,428 for GK and $9,094 for CK. The difference in the total annual costs of the technologies at a level of 200 patients per year would be $64,600 and $197,800 lower for Novalis® compared to GK and CK, respectively. On patient volumes between 100 and 200 per year, the utilization of only one half of a neurosurgeon's time results in a decrease of the average per patient costs in the range of $1,500 to $750 for each SRS technology.

Table 2: Novalis® average costs per patient

Number of patients/year	Investment costs ($)	Maintenance costs ($)	Staff costs ($)	Average cost*/ patient/year ($)
100	5,701	3,500	7,009 (5,509)	16,210 (14,710)
115	4,957	3,044	6,094 (4,790)	14,095 (12,791)
130	4,385	2,692	5,391 (4,237)	12,469 (11,315)
150	3,801	2,333	4,672 (3,672)	10,807 (9,807)
175	3,258	2,000	4,005 (3,148)	9,263 (8,406)
200	2,851	1,750	3,504 (2,754)	8,105 (7,355)
225	2,534	1,556	3,115	7,204
250	2,280	1,400	2,803	6,484
275	2,073	1,273	2,549	5,894

* Staff cost including 0.5 FTE neurosurgeon on the patient volumes between 100 and 200 per year in parenthesis

Table 3: Gamma knife average costs per patient

Number of patients/year	Investment costs ($)	Maintenance costs ($)	Staff costs ($)	Average cost* /patient/year ($)
100	6,008	4,709	6,139 (4,639)	16,856 (15,356)
115	5,225	4,095	5,338 (4,034)	14,657 (13,353)
130	4,622	3,622	4,722 (3,568)	12,966 (11,812)
150	4,006	3,139	4,092 (3,092)	11,237 (10,237)
175	3,433	2,691	3,508 (2,651)	9,632 (8,775)
200	3,004	2,354	3,069 (2,319)	8,428 (7,678)
225	2,670	2,093	2,728	7,491
250	2,403	1,884	2,455	6,742
275	2,185	1,712	2,232	6,129

* Staff cost including 0.5 FTE neurosurgeon on the patient volumes between 100 and 200 per year in parenthesis

Table 4: CyberKnife average costs per patient

Number of patients/year	Investment costs ($)	Maintenance costs ($)	Staff costs ($)	Average cost*/ patient/year ($)
100	6,218	4,536	7,434 (5,934)	18,187 (16,687)
115	5,407	3,944	6,464 (5,160)	15,815 (14,511)
130	4,783	3,489	5,718 (4,564)	13,990 (12,836)
150	4,145	3,024	4,956 (3,956)	12,125 (11,125)
175	3,553	2,592	4,248 (3,391)	10,393 (9,536)
200	3,109	2,268	3,717 (2,967)	9,094 (8,344)
225	2,764	2,016	3,304	8,803
250	2,487	1,814	2,973	7,275
275	2,261	1,649	2,703	6,614

* Staff cost including 0.5 FTE neurosurgeon on the patient volumes between 100 and 200 per year in parenthesis

Table 5: Distribution (%) of costs for each SRS modality

Equipment	Investment (%)	Maintenance (%)	Staff (%)
Novalis®	35.2	21.6	43.2
GK	35.7	27.9	36.4
CK	34.2	24.9	40.9

The results show that the cost differences, especially those between the Novalis® and GK technologies, are relatively small; further changes in the estimated cost parameters may change the order of these technologies. One element in the cost calculation that changes the rankings is the lifetime of the GK equipment (between 10 to 20 years) and the GK radiation unit (between 5 to 10 years). A sensitivity analysis was undertaken to assess the effect on cost if the radiation unit was replaced after 7 years and if the GK was used for the subsequent 8 years with a renewed radiation source. These estimates show that the costs of GK would drop to $15,922 and $7,961 per patient at patient loads of 100 and 200 patients per year, respectively (to $14,422 and $7,211 per patient when 0.5 FTE for the neurosurgeon is used). Changing the replacement time of the radiation unit results in the GK being marginally less expensive that the Novalis® technology. If the life span of GK was 20 years and the radiation unit was replaced only once, the costs would be reduced by about $200 per patient. Cobalt sources have a half life of about 5 years so that the activity and, hence, dose rate is half by 5 years (personal communication, Dr. Barton). The cost savings, which are due to longer utilization times of the radiation source, are relatively small and might even be eliminated as the treatment times will be prolonged due to the lowered radiation levels delivered as the radiation source depletes over time.

This model uses the annuity method to distribute the investment cost and its opportunity cost over the lifetime of the equipment. Though the interest rate (5%) represents a relatively moderate return on investment, such a rate is commonly used in large public investments. If the government preferred to use a 0% interest rate, the CK unit would be the most expensive alternative, followed by the Novalis® technology. At a volume of 100 patients per year, the average cost per patient would be $14,567 for GK, $14,889 for Novalis®, and $16,690 for CK. For GK, the technology with the highest investment cost, a zero capital cost would decrease the basic estimate by $2,300 per patient (see Table 3), assuming a workload of 100 patients per year. On the contrary, higher interest rates would make the Novalis® technology even less costly when compared to both the GK and CK technologies.

Many standard LINAC units require three radiology technicians on staff rather than two technicians, as shown in Table 1. With three technicians on staff the costs per patient would be increased per year by $345 for a patient load of 200 and by $250 for a patient load of 275. In the basic model we assumed that existing facilities would be renovated for Novalis® and CK. If a new facility needed to be constructed for Novalis®, its cost estimates would be very close to the estimated GK costs.

A tentative comparison of the average SRS medical costs to that of microsurgery shows that SRS is less expensive than craniotomy. This applies when more than 124 patients per year are treated with Novalis®, 128 patients per year are treated with GK, and 139 patients per year are treated with CK. If the comparison is made using the DRG costing methodology based on Alberta craniotomy costs ($9,466), the breakeven point will increase to 172 patients for Novalis®, 179 patients for GK, and 193 patients for CK. If the

SRS unit team only requires 0.5 FTE of a neurosurgeon's time, that would decrease the above breakeven point estimates by about ten patients per year.

Van Roijen et al. [12] using microsurgery data obtained from the Netherlands and GK data from Sweden, concluded that the average medical costs for SRS with a workload of 200 patients per year was about $9,990 per patient and for microsurgery $14,050 per patients (exchange: Dfl. 1 = about $0.7). The results from this study showed that the break-even point for SRS and microsurgery was slightly over 100 patients per year.

The estimated SRS-related costs of lost earnings for a patient (3 days) and a caregiver (2 days) is $605, a one night stay at a hotel is $150. If a patient is receiving fractionated SRT (12 days sickness leave), the value of lost working time is $2,783 and the cost of the hotel for 12 nights is $1,800. In the craniotomy alternative, the value of lost working time for the patient (6 weeks) is $3,630. The cost of lost earnings for the caregiver and the family is difficult to estimate in the microsurgery option. The travel costs within Alberta are likely to be similar for all the alternatives.

In the case where a patient needs to travel to Winnipeg, Manitoba for SRS, the patient's and caregiver's related travel and hotel costs will be approximately $1,478 ($1,178 travel costs, $300 hotel costs) and the lost working time costs will be approximately $847 (patient 4 days, caregiver 3 days). The total patient/caregiver related hotel and travel costs plus the costs of lost earnings per SRS treatment in Alberta are $755 and in Manitoba about $2,325 per SRS treatment.

ALTERNATIVES FOR ALBERTA AND WESTERN CANADA

The main objective of this report has been to study the cost implications of different SRS technologies in Alberta. As seen in this study, the results depend on the projected number of patients receiving SRS services per year. If the case load and case mix are not seen to be sufficient to make the SRS business case economically sustainable, the province should consider other sustainable alternatives for these patients.

Alberta Health and Wellness provides public funds for out of province SRS services. During recent years the costs for patients who received treatment in the US have been about $30,000 per patient (does not include travel costs). The costs provided on behalf of patients treated in European centres have been less than half the costs incurred at the US centres. It is likely that the patient costs for Novalis® and CK treatments will be the same as the cost for treatments with GK in these countries. If the treatment option were to send a patient for a treatment to the US, a relatively small patient load per year (about 55 patients) would make Novalis® and GK cost saving for the Alberta health care system. However, it is likely that the number of patients sent to other provinces or countries is much smaller than the number of patients who would likely be treated in Alberta if SRS were available. If SRS is available in Alberta patient numbers would increase because it is inconvenient to send relatively sick patients (e.g. brain metastatic patients) to other provinces or countries and the acceptance process imposed by other treatment centres is lengthy.

In Canada, new GK equipment has been purchased by the Winnipeg Health Sciences Centre in Manitoba with an estimated capacity of 600 patients per year (personal communication, Dr. West) and the province of Quebec has been considering the purchase of its own SRS unit. At the moment, it is difficult to estimate the interprovincial prices for SRS services. It is likely that the Winnipeg based unit will have capacity to treat patients from Alberta and British Columbia at an estimated cost of $15,000 per patient (personal communication, Dr. West). The capacity of the Winnipeg centre will also depend on the possible demand for SRS treatments from other parts of Canada and the US.

DISCUSSION

This basic model shows that the costs for the Novalis® and GK alternatives are relatively similar depending on the assumptions made in the sensitivity analysis. CK is always the most expensive alternative. The patient load requiring SRS services is somewhat uncertain. The estimates provided by the experts suggest that 100-185 patients in Alberta and about 60 patients in British Columbia annually would benefit from SRS and, if the technology were to be used for functional disorders, the patient load could increase by about 30 patients per year. A rough comparison between the costs of SRS technologies and conventional microsurgery suggests that at least some patients with functional disorders should be offered the SRS alternative in addition to those patients with malignant brain tumors, acoustic neuroma, AVM, and trigeminal neuralgia, in order to achieve SRS investment cost savings for the health system (assuming that the lower utilization estimates will happen). CK and Novalis® can be used to treat other cancer patients, so for those techniques the extra resources due to low utilization rates could be used for other patient groups. This utilization option is not possible for GK.

The basic cost model assumes that every patient receives the same treatment. However, it is very likely that CK and Novalis® techniques will be used for fractionated SRT, since that option is being used more frequently by those centres that have these technologies. This implies that fractionated SRT will cost more per patient than single SRS procedures, since fractionated SRT require increased equipment time and staff time. However, one can argue that as long as the main cost factors (investment, maintenance and staff costs) are fixed, the average cost per patient treated can be used to approximate the cost of treatments unless extra resources are required in order to provide services to the next new patient. If only the basic staff costs are included in the model, it is probably possible to provide about 500 services per year (personal communication, Dr. Alexander Chan and Dr. Peter Craighead). This means that about 230 patients could be treated (including 30 patients receiving fractionated SRT) per year without a need for overtime or recruitment of new staff. However, increasing the staff complement by one technician for patient loads over 200 per year has minor cost implications in the model. Once fractionated SRT procedures are included in the opportunity cost framework (benefits lost elsewhere), fractionated SRT is several times more expensive than SRS, assuming that the staff and equipment could be used for other purposes.

The assumptions that the outcomes of the alternatives are similar seem to be in line with the findings from most recent review studies [2, 3, 7]. However, the clinical indications of SRS and microsurgery patients may vary significantly. The size of the lesion and its proximity to sensitive areas may hinder the use of microsurgery for some patients. Therefore, it seems realistic to expect that SRS will be indicated for these patients.

The cost estimations assume that there is no significant difference in the number of short and long-term complications to patients after treatment among the SRS technologies themselves and between SRS and microsurgery. In the study by van Roijen et al. [12] there were no short-term complications noted from the SRS procedures whereas there were some postoperative complications after microsurgery. Patients with acoustic neuroma had more symptoms in facial and trigeminal nerve function after microsurgery (10%) than after SRS (2%) [12]. The SRS group also had significantly better health related quality of life as measured by EQ-5D and SF-36 measures. Since the Dutch study utilized data from two countries (the Netherlands and Sweden), the reliability of the study results are uncertain. It seems to be reasonable to maintain an assumption of similar complication rates among all technologies assessed in the study, since the same basic assumption is also made in other cost estimations.

The comparison of the costs of SRS technologies and the cost of craniotomy is somewhat complicated, since the cost of the craniotomy is difficult to estimate for the heterogeneous patient group that is treated by SRS centres. The primary treatment cost of $13,158 for glioblastoma multiforme craniotomy was based on a complete chart review that included physician costs [13]. This estimate roughly represents the costs for malignant cancer patients (either total or partial resection) and acoustic neuroma patients. The DRG-based craniotomy costs varied between $5,366 and $9,466 partly due to variances in length of stay and if physician fees were included [2,17]. The DRG estimates did not include any costs for post-surgical complications, like infections, hemorrhages and possible facial nerve damage, or the cost for post-operative mortality. Since most of the potential patients for SRS would require relatively demanding conventional operations, the cost estimate of about $13,000 seems to be a more realistic representation for the microsurgery estimate. Assuming that the cost of a craniotomy for conditions such as acoustic neuroma and brain metastatis is about $13,000, the Novalis® becomes cost minimizing for volumes above 124 patients per year and GK above 128 patients per year.

The current cost analysis assumed that the whole team spent their entire working time in the SRS unit. If the unit is running at the lower end of its capacity (especially below 150 patients per year), it is likely that neurosurgeons and other specialists would have some extra time to be used elsewhere. If that extra time is included in the calculation, it could result in reduced (per patient) costs for SRS. It should be noted that the SRS unit could also be used for research purposes.

Koningsmaier et al. [10] published estimated investment costs, operating costs and staffing costs for modified and dedicated LINAC and GK technologies. They estimated that the modified LINAC (used only part time for the treatment of neurological patients) was cost saving up to a volume of 175 patients per year (the upper limit of its capacity) and after that GK became the less costly alternative. The costs for each technology were relatively close to each other. The main reason why GK was less costly in the Koningsmaier et al. [10] study was that they assumed only one radiation unit replacement and a 20 year lifetime for GK. Koningsmaier et al. used higher construction costs for the LINAC than were considered in the costing model for this report. Epstein and Lindquist [11] also used a lifetime of 20 years and one replacement of the Cobalt-60 unit for the GK; they found that GK was significantly less costly than dedicated LINAC starting at a patient load of 100 patients per year.

When the results based on the costing model used in this report are compared to the economic analyses in the Quebec [2] and Australia [7] reports, it can be seen that the results are very similar to those of the Quebec study. The main reason for this is that this study and the Quebec study based their estimates on the cost model of Koningsmaier et al. [10]. However, the Quebec study (see Appendix B) estimated SRS costs to be significantly lower than the SRS costs in this study. The main reasons for this are that the Quebec study used: lower staff costs (lower salaries for physicians and no clerical costs were included), GK radiation unit was replaced after 10 years (5 years in this study), a 20 year lifetime (15 years in this study), and higher construction costs for LINAC. The magnitude of the cost estimates in this study is likely to be closer to the real operating values in Alberta, since this model utilizes the most recent market values available for both investment and maintenance costs and the staff costs are yearly salaries paid in Alberta. As well, the LINAC alternatives of Novalis® and CK are more expensive than older LINAC technologies. However, Novalis® and CK are technically more comparable to GK than previous LINAC technologies and this will allow their use to treat delicate lesions where a high degree of technical accuracy is essential.

The comparison of these results to the Australian study [7] is more difficult because the Australian study used cost estimates obtained from the GK application that did not include reliable cost estimates for investment and also did not provide any estimates for staff and service contract costs. The Australian study concluded that the estimated equipment cost for GK was between 1.7 to 2.9 times more expensive than that for LINAC depending on the costing scenario used. It should be noted that in Australia, for the year 2000 there were eight LINAC units that were modified to treat neurosurgical patient groups.

Most cost studies compared only the direct medical costs of the technologies; that is, the costs paid by health authorities or insurers. Using the societal perspective, the costs to patients and their relatives are also an important part of decision making. The indirect costs to patients receiving the surgical operation seem to be about six times higher than the lost productivity of patients treated with SRS and their caregivers. Indirect costs for patients treated with fractionated SRT are about $850 less than the indirect cost of lost working time for patients receiving microsurgery. However, fractionated SRT will be about about $1,000 more expensive than microsurgery when the patients' hotel costs for a two weeks visit to the SRS centre are included in the calculation. The estimation of lost productivity for patients receiving microsurgery is a somewhat difficult task, because the surgical treatments vary a great deal and thus influence the time off work. For patients who do not work, the cost implications of either option are not large, unless the patient needs to travel from a distant place.

The indirect costs of the patient and their caregiver are relatively similar when out of province SRS services are compared to SRS services in Alberta. However, the Alberta government provides an extra $1,600 for travel and hotel costs when SRS services are provided in Manitoba or even more if the patient goes to a centre in another country.

In the cost analysis, it was not possible to estimate the influence of differences in the severity and/or location of the treated lesions between the SRS and microsurgery alternatives. Since there are no randomized controlled trials on this topic, it is not possible to adjust the cost (and cost-effectiveness) analysis results to include these clinical differences in the treated patient groups.

The biggest weakness of this study is that the cost analysis relies on secondary data sources. It is possible that some cost estimates may change once a dedicated SRS unit is operationalized. It is likely, though, that the cost model and the sensitivity analyses will have predicted feasible cost estimates for Alberta.

CONCLUSIONS

This study shows that there is no significant difference between the costs of dedicated GK and Novalis® units in Alberta. A CK unit seems to be significantly more expensive than the other two alternatives. The current volume of patients in Alberta predicted to be appropriate for SRS is in the range of 100 to 185 patients per year. This number does not include patients who may be referred for SRS from Saskatchewan, British Columbia, and the Northwest Territories.

According to this model, if a 0% interest rate were used and 100 patients per year were treated, the average cost per patient would be $14,567 for GK, $14,889 for Novalis®, and $16,690 for CK. When taking into account the out-of-province travel, hotel expenses and lost earnings for both the patient and caregiver (estimated to be $1,600) as well as the estimated cost of the procedure ($15,000) it appears that the option of establishing a dedicated unit in Alberta should be considered.

From a patient's perspective the SRS technology, where appropriate, is about one sixth of the cost of microsurgery. In the fractionated SRT treatment the cost for the patient and caregiver are significantly higher than for a single SRS treatment.

If the costs were calculated from the societal perspective including both direct medical costs and indirect patient costs, the Novalis® and GK would be cost saving even at a level of 100 patients per year. However, at that operational level, health care resources would not be efficiently used due to excess capacity of the SRS team and of equipment.

Central to the decision concerning SRS in Alberta and Western Canada is the fact that Manitoba will have a GK based SRS unit operationalized sometime in 2003 and Quebec is considering the prospect of a dedicated SRS unit. If Alberta were to invest in a dedicated SRS unit, there is a question as to whether there would be enough of a workload for the Alberta unit, the one in Manitoba, and the other potential unit in Quebec. The field of SRS is changing rapidly (e.g. for functional neurosurgical patients) which makes the projection of the number of Canadian patients very difficult.

APPENDICES

APPENDIX A: PERSONAL COMMUNICATION DETAILS

Canadian Communication Details:

Calgary Health Region, Calgary, Alberta

Dr. Alexander Chan, Tom Baker Cancer Centre, Calgary. Discussion on 22nd April 2002, and correspondence on 14th June 2002 and 2nd April 2003.

Dr. Peter Craighead, Tom Baker Cancer Centre, Calgary. Discussion on 22nd April 2002, and correspondence on 14th June 2002, 29th July 2002 and 2nd April 2003.

Dr. Garnette Sutherland, University of Calgary, Faculty of Medicine, Department of Clinical Neurosciences. Discussion on 22nd April 2002.

Capital Health, Edmonton, Alberta

Dr. Kenneth Petruk from University Hospital of Alberta, Edmonton. Discussions on 9th May 2002 and 15th August 2002, and correspondence on 27th February 2003 and 17th April 2003.

Manitoba:

Dr. Michael West from the University of Manitoba, Faculty of Medicine, Section of Neurosurgery. Correspondence on 27th February 2003.

Quebec:

Dr. Jean Marie Lance from the Agence d'Évaluation des Technologies et des Modes d'Intervention en Santé, Montréal, Québec. Correspondence on 27th February 2003.

Foreign Communication Details:

Dr. Michael Barton from The Collaboration for Cancer Outcomes Research and Evaluation, Liverpool Hospital, Australia. Correspondence on 21st February 2003.

APPENDIX B: KONINGSMAIER ET AL. [10]COST MODEL RESULTS, FROM THE QUEBEC (AETMIS) STUDY [2]

Table 6: Equipment purchase and annual operating costs (Konigsmaier et al. [10])

	Gamma Knife $CAN*	**Dedicated linear accelerator $CAN**	**Modified linear accelerator $CAN**
Equipment cost	7.05 million	2.86 million	1.51 million
Construction work[a]	1.31 million	1.58 million	1.58 million
Total	8.36 million	4.44 million	3.09 million
Annual operating cost			
Staff:	314,300[c]	500,000[c]	250,000[d]
Physicians[b]	*157,143*	*209,524*	*104,726*
Physicists	*95,238*	*95,238*	*33,333*
Other	*61,919*	*195,238*	*111,941*
Material resources[e]	202,190	283,143	228,973[f]
Cost of maintenance alone[g]	*171,429*	*220,000*[h]	*197,143*[h]
Total	**516,490**	**783,143**	**478,973**

*Based on 1995 exchange rate ($1 CAN = 1.05 DM).

[a] The construction work cost varies with the site (e.g.: construction or not, ...).

[b] The medical staff cost is based on the physicians' annual salaries.

[c] Staff costs hold steady up to 200 patients: beyond that, 20% must be added to the basic cost.

[d] Staff costs hold steady up to 100 patients: beyond that, 20% must be added to the basic cost.

[e] These costs are calculated on the assumption that optimal use is made of the equipment and include: water and electricity supply, cleaning, dosimetry, radiation shield tests, and maintenance. Annual cleaning and radiation shield test costs are the same for all equipment. GK radiation unit replacement is after 10 years.

[f] Calculated on the basis of 50% use for SRS.

[g] This cost is fixed, regardless of the number of patients.

[h] Also includes maintenance of SRS accessories.

Table 7: Total cost of treatment per patient based on equipment used [a] (Konigsmaier et al. [10])

Number of treatments	Gamma Knife[b] $ CAN*	Dedicated linear accelerator[b] $ CAN*	Modified linear accelerator $ CAN*
100	12,482 (*10,911*)[c]	12,968 (*10,873*)	8,897 (*7,849*)
150	8,327 (*7,229*)	8,780 (*7,383*)	6,537 (*5,699*)
200	6,249 (*5,463*)	6,536 (*5,488*)	
225	5,836 (*4,998*)	6,265 (*5,147*)	
250	5,254 (*4,500*)	5,649 (*4,644*)	

*Based on 1995 exchange rate (1$ CAN = 1.05 DM).

[a] Total cost includes annual amortization for various capital equipment investments and construction work, annual interest on invested capital calculated at 6% (this item represents respectively $1,005, $618 and $532 per patient in the estimate), annual operating costs and staff costs (including replacement staff), which includes physicians' salaries.

[b] Assuming the service life is 20 years for the Gamma knife and 10 years for the linear accelerator.

[c] The total cost of treatment per patient by equipment type, excluding the physicians' salaries, is indicated between parentheses.

APPENDIX C: WORKLOAD PROJECTIONS/ANNUM IN ALBERTA

Table 8: Estimated number of Alberta patients who would qualify for SRS

Indication	Incidence [1]	Based on 1.5 million people Calgary Health Region [1]	Calgary Health Region patients appropriate for SRS [1]	Alberta Population needs [2]
CNS Neoplasis	11/100,000/yr	165/yr		
Malignant		82/yr	12/yr	60-70/yr*
Benign (acoustic neuroma)		83/yr	25/yr	30-35/yr**
AVM	1/100,000/yr	15/yr	5/yr	10-15/yr
Metastatic cancer	11/100,000/yr	165/yr	40/yr	
Trigeminal neuralgia		30/yr	10/yr***	
Total			92****	100-120****

1 Calgary Health Region estimates
2 Capital Health estimates

* Includes malignant and metastatic cancer
** Includes patients from Western Canada for acoustic neuroma. Other conditions include meningiomas, pituitary adenomas, juvenile pilocytic astrocytomas
*** Microcrosurgery is still the treatment of choice, but those patients who do not respond to microvascular decompression are candidates for SRS (personal communication, Dr. West)
**** Possible functional neurosurgery patients, patients with temporal lobe epilepsy and cognitive neurosurgery patients are not included

APPENDIX D: FIXED COST COMPARISON FOR CK, GK AND LINAC

Table 9: Fixed cost comparisons

	CK	GK	Novalis®
General Installation/Maintenance/Supplies Costs			
Construction	550,000	1,000,000	150,000
Investment	4,500,000	5,500,000	4,320,000
Radiation unit		955,792*	
Disposal		200,000*	
Service Contract	138,744	138,744	138,744
Technical maintenance	176,974**		73,409
Basic supplies	109,570	109,570	109,570
Cleaning	13,500	13,500	13,500
Electricity/water	2,500	2,500	10,344
Radiation test	4,450	17,800	4,450
Administrative Costs			
Receptionist	33,000	33,000	33,000
Clerk III	36,000	18,000	36,000
Nurse clinician	76,358	76,358	76,358
Radiology technicians	138,000	69,000	138,000
Radiation oncologist	75,000	75,000	75,000
Neurosurgeon	300,000	300,000	300,000
Medical physicist	85,000	47,500	42,500

*Changed every 5 years
**Every 2nd year

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